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AN EXPERIMENTAL ANALYSIS OF ASSOCIATIVE FACTORS IN MEDIATED GENERALIZATION[1]

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For more than two thousand years men have concerned themselves with the question of how ideas become associated or connected to one another. One of the first to treat the subject systematically was Aristotle, who stated that there were three ways in which ideas could become associated, through similarity, contrast, or contiguity in time or space. Aristotle's laws passed relatively unchanged through two millennia to become in the eighteenth century the cornerstone for a philosophical school, British Associationism. The associationists, subjecting the problem to careful scrutiny, debated among themselves as to which principles were necessary to explain the "association of ideas." The extremes of this debate were represented by James Mill, who thought only one principle, contiguity, was necessary, and by Thomas Brown, who added four secondary principles to Aristotle's three primary principles.

Currently, all three principles of association remain acceptable; however, modern psychologists are inclined to emphasize some form of contiguity as the most fundamental explanatory concept. Similarity and contrast appear to have their greatest appeal in those situations where an association is observed between elements for which no contiguous relationship can be established. For situations such as these, proponents of the contiguity principle have introduced the notion of mediate association. In the broadest sense, association of the presumably independent elements is assumed to be mediated by associations between these elements and some common term or terms. Thus, while Elements A and B are independent, if they are associated in some manner (not usually clearly stated) with Element C, it is supposed that A and B will acquire some associative connection to each other. The mediate association concept has provided a theoretical basis for explaining generalization phenomena, and the present investigation deals with this application. The concern here is primarily with the importance of the temporal order of associating independent elements with the common element and the direction of association between the independent elements and the common element in the verbal transfer situation.

Mediating Associations

Mediate association may be invoked to explain why two different stimuli elicit the same response (stimulus equivalence), why two different responses are evoked by the same stimulus (response equivalence), or why a stimulus and a response elicit each other without having been previously directly associated (chaining).

Several theories have been proposed which deal with the nature of mediated generalization, and though they differ somewhat as to the exact nature of the mediating process, they all stem from a series of papers by Hull (1930, 1931, and especially 1939). Though not the first to deal with mediated generalization, Hull is usually credited with making explicit the distinction between generaliza-

[1] This manuscript represents the union of two PhD theses (Horton, 1959; Kjeldergaard, 1960) submitted to the Graduate School of the University of Minnesota. The research reported here was conducted as a joint project and the writing responsibilities in the preparation of this monograph were shared equally by the authors. This research was supported by grants from the Graduate School of the University of Minnesota and by the National Science Foundation. The writers wish to acknowledge their indebtedness to James J. Jenkins for his generosity both in time and ideas in the planning of this research and in the preparation of this and related manuscripts.

tion based upon partial stimulus identity, primary generalization, or irradiation, and secondary or mediated generalization (Hull, 1939). Partial stimulus identity is self-explanatory; primary generalization is closely linked with classicial conditioning and is illustrated by the generalization found on a physical gradient surrounding a conditioned stimulus (CS). For example, if we condition a dog to salivate to a tone of 1,000 cps he will also salivate, with a diminished amount, to all tones immediately surrounding 1,000 cps (cf. Bass & Hull, 1934; Hovland, 1937; Pavlov, 1927). Secondary or mediated generalization is used to explain transfer across different physical dimensions and relies on response produced cues, developed through the learning process, as mediating links. The argument developed by Hull is that each response produces its own characteristic proprioceptive stimuli which may then become associated with other responses. Thus, two stimuli associated with a common response may then be said to produce a common proprioceptive stimulus:

Stimulus A ⟶ Response B ⟶ (stimulus consequences of B)
Stimulus C ⟶ Response B ⟶ (stimulus consequences of B)

It is further assumed that Response B can occur implicitly or fractionally and can produce implicit fractional stimulus consequences. Therefore, when one of the stimuli (e.g., A) is associated with a new response (D), this response is also associated with the stimulus consequences of the implicit response B:

Stimulus A - - - → (implicit B) - - - → (stimulus consequences of B)
Response D

It is a simple matter to extend the model to other stimulus and response arrangements through the same general form of analysis. Most of the proposed mediational models now current have been derived from Hull's notion of secondary generalization. These models may be divided into two rather distinctive types: (*a*) representational mediation models such as those of Cofer and Foley (1942), Osgood (1952), and Mowrer (1954); (*b*) associational mediation models like that of Jenkins (1955) and Russell (1955). The former variety places a great deal of emphasis on the nature of the mediation process, as opposed to its effect. The clearest formulation of this model is that of Osgood which is based on Hull's fractional goal response. It is asserted that the implicit mediating link in the process is a fractional response which is attached to both stimulus elements. The associative models, although not explicitly formulated, appear to require some sort of implicit verbal mediating link which, in some ways, is similar to the implicit verbal chains proposed by Skinner (1957).

A frequently cited example of mediated association is that provided by the experiments of Shipley (1933, 1935) and Lumsdaine (1939). Although a single paradigm is usually cited for this research actually two widely different paradigms were used. The so-called Shipley-Lumsdaine paradigm is ordinarily given as:

Stage 1: A (light) ⟶ B (wink)
tap on cheek

Stage 2: B (wink) ⟶ C (finger withdrawal)
tap on cheek shock

Test Stage: A (light) - - - → (implicit B wink) - - - → C (finger withdrawal)

This is a simple chaining paradigm with an implicit middle term functioning as a mediating link on the test trial.

Shipley's (1935) paradigm is given as follows:

Stage 1: A (light) ⟶ B (wink)
tap on cheek

Stage 2: C (buzzer) ⟶ B (wink)
tap on cheek

Stage 3: A (light) - - - → (implicit B) - - - → D (finger withdrawal)
shock

Test Stage: C (buzzer) - - - → (implicit B) - - - → D (finger withdrawal)

This is a stimulus equivalence model, similar to Hull's, and is more complex than the chaining paradigm in that B never acts *explicitly* as a stimulus, serving only as an implicit response-stimulus unit in the third stage, where it acquires an association with D, and again serving implicitly in the test stage, where it evokes D as a response.

These models provide a basis for explaining certain generalization phenomena but suggest several additional paradigms as well. Investigation of all of these paradigms would seem to be necessary to provide an adequate basis for evaluating the "explanations" which invoke mediate association. Combining word pairs in such a way that mediated generalization may be tested in a three stage paired-associate learning problem yields eight possible paradigms.

	I	II	III	IV	V	VI	VII	VIII
Stage 1:	A ⟶ B	B ⟶ C	B ⟶ A	C ⟶ B	A ⟶ B	C ⟶ B	B ⟶ A	B ⟶ C
Stage 2:	B ⟶ C	A ⟶ B	C ⟶ B	B ⟶ A	C ⟶ B	A ⟶ B	B ⟶ C	B ⟶ A
Test Stage:	A ⟶ C	A ⟶ C	A ⟶ C	A ⟶ C	A ⟶ C	A ⟶ C	A ⟶ C	A ⟶ C

FIG. 1. The eight paradigms.

Paradigms I, II, III, and IV are "chaining models" suggested by the Shipley-Lumsdaine work, V and VI are "acquired stimulus equivalence models" suggested by the work of Hull, while VII and VIII are referred to as "acquired response equivalence" models. Although Paradigms I, V, and VII have been treated by several investigations, the remaining ones have scarcely been studied at all. The present study is concerned with the extent to which generalization occurs in these eight paradigms as well as the adequacy with which an associative model accounts for such effects.

Review of the Literature

The earliest studies on mediate association were done by Scripture (1892), Smith (1894), Howe (1894), and Atherton and Washburn (1912). The results of these investigations were conflicting. In addition, the experimental situations were highly variable, the materials used were not constant, and they were all oriented, primarily, at discovering the "level of consciousness" at which the mediation, if any, took place. Thus these early experiments shed little light on the mediational process as we are concerned with it here.

Modern experimental investigations of mediational models go back at least to the work of Shipley and Lumsdaine cited above. Their research, of course, dealt with nonverbal processes although the paradigms have more typically been tested with verbal materials using the paired-associate learning technique. In this situation the subject is asked to learn pairs of words. The left-hand terms serve as stimuli and the right-hand terms as responses. Several lists are learned in which common terms are arranged in accord with the paradigm being tested. The explanation of generalization or facilitation in such cases is made on the basis of mediate association. It is assumed that the common term occurs implicitly between the elements used during the test stage and thus facilitates the learning process.

The first systematic test of any of the paradigms used in this investigation was by Peters (1935), who ran a series of nine experiments using several of the paradigms. Although he treated all of his experiments as if the paradigm involved were the same, in essence he tested Paradigms I, V, and VII. He has been credited with testing Paradigm VI also, but in the experiment referred to, the stimuli are not discriminable from responses in both learning stages, thus one cannot specify which of the four stimulus and response equivalence paradigms was involved here.[2]

Results from Peters' experiments were mixed. Even where he found positive results, the same paradigm and procedure with slightly different materials was not likely to confirm his previous finding. This was true for all of the paradigms that he tested. Where facilitation did occur Peters discovered that the majority of mediation responses were produced by a few subjects. This factor suggests some sort of individual parameter which might be a function of a variable such as the amount of overlearning in Stages 1 and 2.

Of the methodological difficulties involved in Peters' experiments, the most serious seems to be the nature of his test stage. In six of the nine experiments, Peters depended upon a recall test. Since the learning in Stages 1 and 2 was carried only to a relatively low level, such a test might have been insufficiently sensitive to detect mediational bonds which were present. Further, in several of these experiments recall was tested, not immediately following the learning phases, but 24 hours later, again decreasing the likelihood of detecting a mediational effect.

In the three experiments in which Peters used a "trials and errors to criterion" test in the third stage, the results were negative for Paradigms I and VII and significant in the wrong direction for the indeterminable paradigm (see Footnote 2). It has been shown that generalization effects are most prominent in the early phases of the test trials (Haagen, 1943; Osgood, 1948; Underwood, 1951); thus, this too provides an insensitive test of mediated generalization.

To sum up: Although Peters tested at least three and perhaps four of the paradigms discussed earlier, due to the variety of procedures and experimental materials, direct comparisons are possible only for Paradigms I with V and I with VII. Here, lack of a sensitive test stage and negative results leave the findings in question. Further, the unreliability of the finding involving the same paradigm and similar methodology, and the lack of statistical tests for most experiments leave the significance of all the Peters experiments in question. Certainly, the presence of mediational effects is strongly suggested in some cases.

Irwin (1951) performed one of the few experiments using a chaining paradigm other than the Shipley-Lumsdaine model (our Paradigm II):

Stage 1: B ⟶ C
Stage 2: A ⟶ B
Stage 3: A ⟶ C

[2] The experiment referred to here is Peters' experiment Number 7. The stimuli and responses to be associated in the learning stages involved two figures, the larger circumscribing the smaller, presented to the subjects simultaneously. Unless one can assume that when the subject was told to associate the larger with the smaller that the subject then perceived the larger as a stimulus and the smaller as a response, there is no way of determining which paradigm is involved here, only that it is either stimulus or response equivalence.

Facilitation was found in this situation. It can be seen that this paradigm is the same as the classic chaining model except that the order of Stages 1 and 2 has been reversed. Generalization in this case can be mediated via the implicit B term occurring during the test trial or by the implicit occurrence of C as a response to B in Stage 2 or by both of these processes.

Bugelski and Scharlock (1952), using nonsense syllables, demonstrated facilitation with the simple chaining paradigm used by Peters. The mediational effect occurred even though the subjects did not report deliberate use of the common term as a memorizing device. In this experiment, similar to Peters', the paired-associate technique was used and all associations were formed within the context of the experiment.

A rather interesting demonstration of chaining, involving two links, was presented by Russell and Storms (1955). They used associative chains taken from word association tables (Russell & Jenkins, 1954) as the first stage of their experiment. Chains of the $B \longrightarrow C \longrightarrow D$ variety were selected from the tables (e.g., Justice $\longrightarrow$ Peace $\longrightarrow$ War). The study was restricted to those chains where D was never given as a free response to B and vice versa. A nonsense syllable was used as a stimulus to evoke the B term, which then presumably set off the chain leading to D. The paradigm was as follows:

Assumed:	$B \longrightarrow C \longrightarrow D$
Stage 1:	$A \longrightarrow B$
Test Stage:	$A \longrightarrow D$

If the $C \longrightarrow D$ link is viewed as a single term the paradigm is the same as that used by Irwin and the demonstrated facilitation can be explained in the same way.

Mink (1957) compared Paradigms I and VII. He assumed the first stage, on the basis of response frequencies in the Russell-Jenkins norms (1954) for the Kent-Rosanoff Word Association Test, and used a single undifferentiated motor response in the learning stage. The final stage tested generalization of the motor response to associates of the words presented in the learning stage. The paradigms tested were:

	I	VII
Assumed:	$A \longrightarrow B$	$B \longrightarrow A$
Stage 1:	$B \longrightarrow C$ (motor response)	$B \longrightarrow C$ (motor response)
Test Stage:	$A \longrightarrow C$	$A \longrightarrow C$

Generalization was obtained with Paradigm VII, but not with Paradigm I. Mink hypothesized that the impilicit B in the test stage of Paradigm I offered the subject a chance to make a discrimination not possible in Paradigm VII. When paired-associate learning is used for all three stages and a different motor response is paired with each stimulus, facilitation is obtained with both paradigms, and the chaining model shows a greater transfer effect (Jeffrey, 1957). Thus, Mink's findings may be restricted to the particular situation in which they were obtained.

Jeffrey and Kaplan (1957), using nonsense syllables in a paired-associate learning task, tested Paradigm VII and obtained positive results. Later Jeffrey (1957), pairing nonsense syllables with six motor responses, tested both Paradigms I and VII and found significant generalization for both paradigms. The amount of generalization for Paradigm I was significantly greater than for VII for one subgroup; no differences between paradigms were found in the other subgroups. These findings might be reconciled with those of Mink's if one assumes that the different tasks, i.e., learning to associate a specific response with each stimulus versus learning to discriminate between sets of stimuli to which a single response is to be made or not made, give rise to different response sets and thus to different strategies.

As one reviews the literature on the eight paradigms outlined above, one is impressed with the inequitable use of the various paradigms in research. Some paradigms are used frequently, others not at all. This may

be due to the investigator's treating all of the paradigms as if they were alike and then choosing one or a few as a matter of convenience. This explanation is particularly plausible for the early experimenters such as Peters, who seems to have done just that. Another possible explanation is that the researcher, after performing an analysis of the possible occurrence of implicit responses or associations, has selected for study only those paradigms which seem most likely to produce "good" implicit chains. It may be that some of the paradigms have been ignored because they seemed unlikely to elicit *any* mediating responses. However, if one admits the possibility of bidirectional or backward associations being formed in paired-associate learning, then there is some possibility of mediational effects in all of the paradigms. There is evidence which seems to warrant careful consideration of this possibility. This evidence stems from four major sources. Russell (1955) reviewed the work done at Minnesota dealing specifically with this problem. Evidence was cited from such varied sources as clustering during recall (cf. Jenkins & Russell, 1952), tachistoscopic recognition time (O'Neil, 1953), paired-associate learning, etc. Much of this work involved the use of stimuli and responses from the Minnesota norms for the Kent-Rosanoff words for which the forward and reverse strengths of the word pairs are known; however, even when the stimulus and response terms were nonsense symbols, most of the above experimental conditions yielded evidence favoring bidirectional associative links in interpretation.

Storms (1957, 1958) designed a series of experiments to investigate alternative explanations of "apparent backward association." In one of these experiments he compared Paradigm I with Paradigm VII, using nonsense syllables as experimental materials, and found no evidence for either forward or backward facilitation. A second experiment involving only Paradigm VI, using as its experimental materials word pairs selected from the Minnesota norms so they had a moderate forward (A⟶B) strength, but virtually no detectable reverse (B⟶A) strength, showed strong generalization effects for both forward and backward pairs.

In a different type of experiment, Storms demonstrated that the mere presentation of a response member of a low strength S⟶R chain can greatly boost, at least temporarily, the apparent strength of this S⟶R pair. This study was cited in support of a proposed "recency factor" explanation. Storms feels that this recency factor can account for much of what is presumed to be "backward association" in literature, i.e., "backward association" effects are the result of forward associations which are normally at low strength, but have received a temporary boost due to the response term having recently been presented. He does not conclude, however, that recency can completely account for the phenomenon.

Murdock (1956, 1958), in two experiments, obtained data which support the view that backward association is in fact a real phenomenon, not accounted for by chance connections or mere recency effects. Using the transference and interference paradigms, he found both transference and interference, forward and backward, where predicted. In each case, the difference between the amount of facilitation or of interference between forward and backward pairs favored those in a forward direction, but these differences were small and statistically not significant. Forward and backward pairs differed significantly from the controls for both the interference and the transfer paradigms.

Jantz and Underwood (1958) used a paired-associate learning task, in which nonsense syllables (stimuli) were paired with adjectives (response), to determine the influence of the number of S⟶R exposures and the association value of the nonsense syllables on the formation of backward (R⟶S) associations. Two tests were utilized: First, after a given number of S⟶R presentations, the subjects were given the R term (adjectives) and asked to recall the S words (nonsense syllables). Secondly, the same subjects were then given the R⟶S pairs on a memory drum and required to learn them to a criterion of one perfect trial. Both the frequency with which the R word elicited the correct S word in the recall task and the amount of facilitation

found in the second stage of the transfer paradigm proved to be a joint function of the two independent variables, the number of S——→R pairings, and the association value of the nonsense syllables involved. Of particular interest are these authors' findings that the strength of both the S——→R and R——→S connections appear to be an asymptotic function of the number of S——→R pairings and that the asymptote for the S——→R connections is considerably higher than the asymptote for the R——→S connections. These findings are consonant with one of the theoretical assumptions to be put forth shortly.

This brief review of the literature illustrates several points. First, there is evidence for mediated generalization in a wide variety of verbal experiments. Second, there is enough evidence for the concept of bidirectionality of associational links that bidirectionality cannot be dismissed as an artifact of the experimental procedures or the organism's learning history. Third, there is a dearth of comparisons between the above illustrated paradigms even though such comparisons would bear directly on the issue of the bidirectionality of associations, and have important general theoretical implications for mediated generalization.

Analysis of the Paradigms

One additional point is apparent from the literature, namely, that the majority of investigators in this area have failed to exploit fully the possibility of implicit associations occurring prior to the test stage; there does not, however, seem to be any justification for such a restriction. Irrespective of the type of implicit responses that one talks about, it appears that the process should operate in all instances of the same task. Consider the situation in which learning is confined to the experimental setting. When the subject learns the first pair of elements no additional associations are likely to be strengthened. This ignores, of course, associations to the stimulus or response elements which occur irrespective of the familiarity of the materials. But during Stage 2, in all paradigms, the formation of other links is possible. Theoretical precedent, for this assumption, was established in the third stage of the Shipley (1935) model, and it is a simple matter to extend the process to the second stage of the three-stage paradigm. For example, the process can be viewed by reference to Figure 2.

Now, in addition to mediation via the familiar, implicit B term during the test stage, another association (indicated by the dotted line) is suggested. The effect of this linkage, established during Stage 2, can be viewed in at least two ways. First, since both the processes separately facilitate the learning of A——→C pairs, during the test stage the combined effect could increase this facilitation. However, at the start of the test trials, the A——→C and A——→B links could be considered as competing tendencies which would delay the learning process. The essential point to be made here is that consideration of such linkage provides a basis

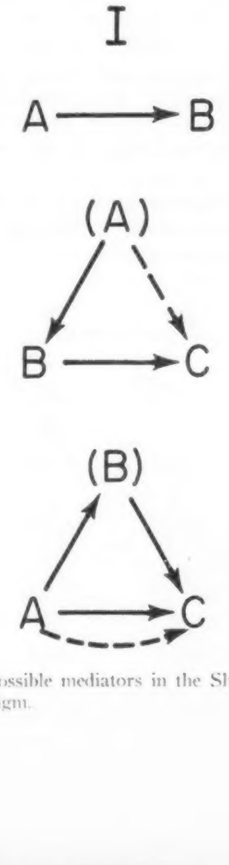

FIG. 2. Possible mediators in the Shipley-Lumsdaine paradigm.

for explaining different generalization effects between paradigms which would not otherwise be possible. To illustrate the above point, the eight paradigms will be analyzed in terms of possible mediating links which could be active in generalization if it should take place. The symbols to be used are as follows:

⟶ indicates a forward explicit association operating in the learned direction

⟵ indicates an association operating in the opposite direction from which it was learned—this will be called a reverse association

( ) indicates a presumed implicit response

---→ indicates a presumed implicit forward association between two terms

←--- indicates a presumed implicit reverse association between two terms

The eight paradigms to be analyzed may be conceptualized as indicated in Figure 2.

The symbols and the analysis of the paradigms presented in Figure 3 can be clarified by examining Paradigms I and V. The first stage in both cases involves, simply, overt paired-associate learning (A⟶B). The second stage, in addition to the overt learning, presumably provides the opportunity for implicit associations to an implicit response which occurs as a result of the first stage learning. In Paradigm I, the implicit response (A) is assumed to occur whenever the overt Stimulus B appears. This, presumably, is the result of the formation of a reverse association (A⟵B) during the

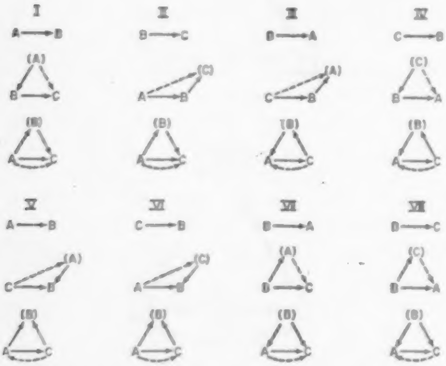

FIG. 3. An analysis of possible mediators in three-stage paired-associate learning.

Stage 1 learning (A⟶B). This implicit response or its stimulus consequences could then become attached to the overt Response C, thus establishing an (A)---→C association. In the test stage, the A⟶C learning may be facilitated via the overt chain formed stepwise during Stages 1 and 2, or through the postulated implicit chain formed during the second stage, or both. In the second stage of Paradigm V, the implicit (A) is presumably elicited by B as a result of the reverse association (A⟵B) formed during the A⟶B learning of Stage 1. The Stimulus C may then become attached to the implicit response, (A), resulting in a C⟶(A) bond. If learning a C---→(A) association results in the formation of an A---→C connection, then facilitation or generalization should be demonstrated in the test stage. In addition, the A⟶B connections and the C⟶B links formed in the learning stages may have some facilitative effects in the test stage of Paradigm V.

The importance of this kind of analysis may be illustrated by contrasting Paradigms I and II. These two situations reveal one essential difference, namely the nature of the A---→C link established during the second learning stage. In view of this, differences in generalization effects between the two paradigms would indicate a contiguity factor in mediated association which would be of considerable importance. Further, it becomes readily apparent from this analysis that if we restrict ourselves to forward associations, generalization effects can be expected only from Paradigms II (all forward links) and possibly from Paradigms I and VII where purely forward links are restricted to the test stage and second stage, respectively.

An Associative Model for Mediated Generalization

Generalizing from the available literature and based upon the analysis of the eight paradigms presented above, an associative model for mediated generalization will be put forth in order to generate specific hypotheses about the generalization effects and the relationship of the effects among the eight paradigms tested here.

The model to be presented represents an extension of the associative type of mediational model proposed by Jenkins and Russell. This model is to be restricted to purely verbal, paired-associate learning. This is not to say, of course, that these notions are not applicable to the nonverbal situation but simply that such application is not of concern here.

The assumptions of the proposed model are:

Assumption 1. All secondary generalization, in paired-associate learning, is mediated in an associative manner. Beyond the analysis made here the exact nature of this process will not be specified.

Assumption 2. Once an A⟶B habit has been established the presentation of A will tend to elicit B, explicitly or implicitly, and this will be true in all situations in which A is involved.

Assumption 3. The establishment of a habit A⟶B simultaneously establishes a habit B⟶A, so that the occurrence of B in any situation tends to elicit A, explicitly or implicitly.

Assumption 4. In establishing an A⟶B habit, the tendency of A to elicit B will at all times be stronger than the tendency of B to elicit A. The exact nature of this function shall remain unspecified.

Assumption 5. Upon establishing a habit chain A⟶B⟶C, each subsequent occurrence of A will tend to elicit both B and C, and the strength of each tendency will depend upon contiguity. The closer the contiguity, the stronger the relationship. (In the above chain A ⟶ B is stronger than A ⟶ C.)

Assumption 6. Upon establishing a habit chain A⟶B⟶C, there develops a tendency for C to elicit both A and B, and the strength of this tendency depends upon contiguity; the closer the contiguity in the learning situation, the stronger the reverse chain. (In the example here, the tendency of C to elicit B is stronger than the tendency of C to elicit A.)

Assumption 7. The directionality of an implicit association takes precedence over the contiguity of such an association so that a forward remote association is a more effective mediator than a reverse contiguous association. This, of course, assumes that the frequency of exposure of these connections is equal.

Assumption 8. For all habits there exists a certain threshold and the strength of a given habit must exceed this threshold before it will manifest itself. This assumption refers to the frequency with which word pairs must be presented to any given subject, and of course holds only on the average, since individual pairs may in some way be especially easy or difficult to learn. Such case or difficulty is presumably a function of stimulus overlap, either in the visual or auditory sense, of the type referred to as primary stimulus generalization or some function of previous contiguities in the particular histories of the subjects.

Hypotheses and Predictions

On the basis of the above set of assumptions and the analyses of the eight paradigms as presented earlier, the following hypotheses are generated (note that Hypotheses 2, 3, and 4 are based on the analyses of the implicit and explicit associations which take place during the second learning stage:

Hypothesis 1. All paradigms will show significant generalization effects. Insofar as each of the eight paradigms has the possibility of mediational links being formed in the second stage or being represented in the test stage, some generalization can be expected to occur.

Hypothesis 2. Paradigms I, II, VI, and VII jointly will show a greater amount of generalization than Paradigms III, IV, V, and VIII together. Paradigms I, II, VI, and VII all involve forward A---→C links being established in the second stage learning, two contiguous and two remote; whereas Paradigms III, IV, V, and VIII involve backward links (A←---C) being formed in the second stage, again two contiguous and two remote. This hypothesis can be most easily illustrated by contrasting the two stimulus equivalence paradigms with each

other or by comparing the response equivalence paradigms. Figure 2 clearly shows that the only difference between paradigms within each of these subsets is the directionality of the implicit association formed in the second stage learning. Similar comparisons are possible with the remaining paradigms.

Hypothesis 3. Paradigms I, IV, VII, and VIII jointly will show a greater amount of generalization than Paradigms II, III, V, and VI taken together. Here it is postulated that the response equivalence paradigms and two of the chaining models will show greater generalization than the stimulus equivalence paradigms and the other two chaining paradigms due to the contiguity factor involved in the second stage learning. In Paradigms I, IV, VII, and VIII the stimulus evokes the mediational response which presumably may then be directly connected to the response term; whereas in the stimulus equivalence models and chaining Paradigms II and III, the response member elicits the mediational response which then must be connected to the stimulus member remotely. To exemplify this hypothesis, we might compare Paradigms I with II and III with IV. Here the associative connections are the same except for differences in the contiguity of the mediator in the second learning stage.

Hypothesis 4. Considering simultaneously the two basic postulated factors, directionally and contiguity, the paradigms can be divided into four groups of two paradigms each (in terms of the anticipated generalization effects). The positions of Paradigms I and VII as being the strongest set of paradigms and III and V as being the weakest set are derivable from Hypotheses 2 and 3; consequently, this hypothesis adds only a prediction about the four remaining paradigms. It is predicted that Paradigms II and VI will show more generalization in the test stage than Paradigms IV and VIII. This is deliverable from Assumption 7, namely that directionality is more influential than contiguity.

Insofar as the analysis of the eight paradigms tested here shows no two paradigms to be exactly alike in terms of possible mediating links, one would extend Hypothesis 4 to make specific predictions about the anticipated generalization effects for each paradigm. However, this would necessitate further assumptions, or extensions of the assumptions already put forth. Such an extension seems premature at this point.

To illustrate by example the difficulties in making further predictions at this point we need only to examine the effects of the mediational links in the test stage. Except for Paradigms I and II where the analysis appears uninvolved, it is difficult to say what effects, if any, the mediators in the third stage will have. Consequently, except for Hypothesis 1, the above predictions are based primarily upon an analysis of the second learning stage. Further predictions would seem to be contingent upon further empirical evidence about the relative generalization effects of these eight paradigms and information concerning what is happening in the test stage.

Summary

The present study deals with the role of mediate association in verbal paired-associate learning paradigms. Although the history of mediate association goes back to Hull's work in the 1930s and the experiments of Shipley (1933, 1935) and Lumsdaine (1939), a surprisingly small amount of research has been done on the topic. Most of the research that has been carried out in this area was performed with verbal materials in the context of paired-associate learning. These studies have suggested several factors such as reverse associations (Storms, 1957) and contiguity which may be important in the mediation process. Furthermore, they provide a basis for extensions of the model to other phases of the learning situation which could provide important information about transfer processes in general.

Eight paradigms are tested here, two in which stimuli are experimentally equated, two in which responses are experimentally equated, and four in which ($S \longrightarrow R_1$, $R_1 \longrightarrow R_2$) response chains are established. Five of these paradigms have been investi-

gated before with mixed results; the other three completely ignored. Seldom have any of these paradigms been compared directly with each other using the same materials and procedures. Where comparisons have been made, they have involved only two of the eight paradigms at any one time.

The paradigms involved are designed to shed light on the effectiveness of the various implicit links formed in connecting stimuli and responses, where effectiveness is measured by ease of learning in the test stage. The primary importance of this study lies in the detection of the presence or absence of generalization effects in the eight paradigms tested, insofar as these effects may then be attributed to the directionality of the associational links and the contiguity of the mediators in the various stages. Secondarily, differences between the paradigm effects, if found, would also reflect on the tenability of the two postulated mechanisms.

Method

Description of the Task

From the standpoint of the subjects, this experiment appeared to involve a series of paired-associate learning problems. The subjects were required to learn two lists of words to a specified criterion, and were then tested on a third list for a fixed number of trials. Each list consisted of eight pairs of words, and the lists were constructed in such a way that the third list was composed of four pairs which had a common associate in the first two lists and four pairs which had no such connection. This procedure can best be illustrated by an example (stimulus equivalence)—see Table 1.

TABLE 1

PAIRED-ASSOCIATE LISTS

Stage 1 List x	Stage 2 List y	Test Stage List z
$A_1 - B_1$[a]	$C_1 - B_1$[a]	$A_1 - C_1$
$A_2 - B_2$[a]	$C_2 - B_2$[a]	$A_2 - C_2$
$A_3 - B_3$[a]	$C_3 - B_3$[a]	$A_3 - C_3$
$A_4 - B_4$[a]	$C_4 - B_4$[a]	$A_4 - C_4$
$A_5 - B_5$	$C_5 - D_1$	$A_5 - C_5$
$A_6 - B_6$	$C_6 - D_2$	$A_6 - C_6$
$A_7 - B_7$	$C_7 - D_3$	$A_7 - C_7$
$A_8 - B_8$	$C_8 - D_4$	$A_8 - C_8$

[a] Identical words.

In the first stage, the subject learns, by the method of anticipation, to associate a particular B word with a particular A word. In Stage 2, four of the same B words are again used as responses and associated to four C words. Four other C words act as stimulus members of C⟶D (control) pairs. In the final stage, the test stage, all of the A words from List x are paired appropriately with all of the C words from List y. During the test stage, the A⟶C pairs which have in common an association with a B word will presumably be learned faster than A⟶C pairs with no such connection. The amount of generalization is then inferred from the number of correct anticipations of mediated A⟶C pairs versus the number of correct anticipations of nonmediated A⟶C pairs. It should be noted that for any subject, all of the A words had occurred with equal frequency in Stage 1 and all of the C words with equal frequency in Stage 2, thus controlling for any differences which might result from unequal familiarity with the material. The same general principles were followed for the remaining paradigms.

Learning Materials

In order to test adequately the generalization effects in this experiment it was felt that the stimulus materials should be relatively unfamiliar to the subjects and that there be no known connections between the stimuli. Ordinarily nonsense syllables are used for this purpose. However, learning lists of nonsense syllable pairs is much more difficult and time-consuming than learning more familiar material. Furthermore, it was felt that nonsense syllables would require a higher degree of overlearning in Stages 1 and 2 to establish levels of associative strength which would be stable enough to demonstrate generalization in the test stage. In view of these considerations real words were used rather than nonsense syllables.

Five-letter words, occurring very infrequently in print, were selected from *The Teacher's Word Book of 30,000 Words* (Thorndike & Lorge, 1944). Thus real words were used, words which had the phonemic and distributional properties of the subjects' native tongue, and yet which were relatively unfamiliar to the subjects and consequently unrelated to each other.

Approximately 200 words were selected for preliminary investigation[3] and 110 were eliminated as being too difficult to pronounce or having strong obvious associations. The remaining 90 words were mimeographed in a two-page booklet in the form

[3] The frequency criterion used here was that a word must have occurred at least .25 times per 1,000,000 words on the general count, but not more than 2/1,000,000 on the Lorge magazine, Lorge-Thorndike semantic, and Thorndike 1931 general count.

of a free association test. This test was administered to 98 students in introductory psychology classes at the University of Minnesota.

The results of the free association test provided the basis for eliminating words which suggested strong common associates. Twenty-eight words with a frequency of common response ranging from 3 to 34 (median = 11) were selected for the experiment proper. Thus all of the words had relatively heterogeneous associations, although the association values were high, ranging from 66 to 93% (median = 83%). It should be noted, however, that most of the associations given to these words were either of the clang variety (e.g., krone-prone) or were based on the formal characteristics of the stimulus words (e.g., draff-draft).

The 28 words were randomly divided into three lists of 8 words each and a fourth list which consisted of the 4 words to be used as controls. The lists were as follows:

List 1	List 2	List 3	List 4
MERLE	NADIR	ARRAS	PRAWN
BANAL	DELFT	KRAAL	GNOME
KRONE	CAIRN	DAVIT	TRIPE
UMBER	VENAL	BLEAR	NILUM
FAGOT	WINCH	REAVE	
SWALE	ETUDE	BEDEW	
DRAFF	LLANO	LIMBO	
TRYST	TAUPE	NONCE	

Since the ease with which particular words or word pairs are learned constitutes an extraneous variable in this type of experiment, several controls were utilized to reduce any such effect to a minimum.

1. The words in each experimental list were randomly paired with the words in every other list. This provided six different lists of pairs since an independent randomization was carried out when the word lists appearing in the stimulus and response positions were reversed.

2. To control for any effect which might result from having the words in a particular experimental list appear only in the first or second stage, or only in the stimulus or response positions, each of the six lists mentioned above was used in the test stage an equal number of times for all paradigms. Since the connections in the test stages vary, the preceding stages necessarily vary to agree with the basic paradigms.

3. The control words were randomly substituted for half of the experimental words in the list common to the first two stages. For any given paradigm this substitution was made in the first stage for half the cases and in the second stage for the other half. With the chaining paradigms, this coincidently resulted in the control words appearing on a 50–50 basis with respect to the stimulus and response positions. This control necessitated 6 additional list or 12 lists of pairs in all.

4. Five randomizations in the order of each group of eight pairs were made to prevent serial learning. One restriction, that no pair could appear twice in succession, was imposed on this randomization process.

Apparatus

The apparatus used in this experiment was a Hunter 403 Cardmaster. The function and performance of this instrument is similar to that of a memory drum, except for the mode of stimulus presentation. Instead of a tape on a revolving drum, the cardmaster utilizes plastic cards exposed at a predetermined rate, for presentation of the stimulus materials.

The primary advantage of the cardmaster over a memory drum, for this experiment, is the facility with which the stimulus materials may be changed. With each subject being exposed to 3 different lists of word pairs, eight paradigms being tested simultaneously, and 12 different lists being used for any single paradigm, this was a practical consideration.

The experimental words were typed on plastic tape and affixed to the approximate center of each half of the 3.5" × 6" plastic cards. All letters were typed in pica capitals.

The materials to be learned were exposed to the subject in the following order: stimulus word alone —2 seconds, stimulus and response words together—2 seconds, interpair interval—2 seconds. The cardmaster automatically returned each card, once exposed, to the end of the list so that there was no lapse of time, other than the 2-second interpair interval, between the end of the list and the beginning of its repetition.

Subjects

The subjects for this experiment were female students enrolled in introductory psychology classes at the University of Minnesota. These students, mainly sophomores, either volunteered directly in class for the experiment or indicated on their class registration cards that they were willing to participate in an experiment. The latter groups of subjects were contacted by postal card or telephone, or both. One hundred and fifty-seven subjects were used although 13 had to be eliminated for failure to learn one of the first two stages in the required 35 trials. Allowing the subject to continue beyond this point would have precluded the possibility of the subject finishing the experiment in the 50-minute time available.

The experimenters restricted themselves to female subjects for two reasons. In the first place females are generally superior to males in verbal tasks (Anastasi, 1958) and it was felt that using females would permit a higher percentage of subjects to finish within the time allowed. Second, restricting subjects to one sex helps to minimize experimental error, consequently providing a more sensitive test of the hypotheses involved.

Procedure

The experimental room contained two tables and two chairs. The subjects were brought in individually and seated in a chair facing the table on which the cardmaster was placed. The stimulus material was kept on the second table, behind the first, but out of the subject's direct line of vision. When the subject was seated, the experimenter read the following directions, switched on the apparatus, and took a seat behind the subject, in full view of the cardmaster:

INSTRUCTIONS

Part I

This experiment is concerned with some of the factors involved in verbal learning, specifically with the way in which pairs of words are learned.

You will be asked to learn several lists of word pairs, each list consisting of eight such pairs. When the experiment begins, two shutters will cover this window [pointing to the cardmaster window]: the shutter on the left will rise first, exposing a word; then the shutter on the right will rise, exposing a second word which will always be paired with the first word.

Your task will be to pronounce the left-hand word aloud when it appears, and then try to anticipate the right-hand word before the shutter rises. If, after saying the word on the left, you have no idea what the right-hand word is, or if you should guess the word incorrectly, then read aloud the right-hand word when it appears.

Do you have any questions?

It is important that you be familiar with the sound of these words as well as their spelling, so I am going to give you this deck of cards [hands cards to subject] which has the words to be used typed on them. I want you to look at each word and then say it aloud.

Now I will read the words to you once, in pairs, as they will appear in the window. This will help you become more familiar with the sound of the words and make learning the list easier.

[Read the fifth randomization to subject.]

When the machine is started, remember to say the words aloud and to try to anticipate the right-hand word of each pair as soon as you can.

Part II

This part of the experiment will be just like the first except some of the words will be different. Here is a deck of cards like the other one I gave you. [Hand deck to subject.] Go through the deck reading each word aloud as you did before. Again I will read the pairs to you to give you an idea of what to expect.

[Read fifth randomization to subject.]

Remember to pronounce the words aloud.

Part III

This part of the experiment will be like the previous ones, except no new words will appear and the pairings will be different. I will read the pairs to you once and then we will begin.

[Read fifth randomization to subject.]

The somewhat novel technique of reading the pairs of words to the subjects was the outcome of a pilot study. This procedure appeared to reduce the amount of time required to learn the lists of pairs without interfering with the results of the third stage. The fifth randomization was read prior to the presentation of the lists on the cardmaster. Thus the subject would not have the same order of pairs read to her that would appear in the first randomization on the cardmaster.

The pilot study also indicated that a satisfactory learning criterion for the first two stages would be three successive errorless trials. This allowed moderately strong associations to be built and yet was attainable by most subjects within the 50-minute experimental session.

Five trials or randomizations were given to each subject on the third stage. Further practice resulted in a decrease in apparent generalization due to the subjects' learning all of the pairs.

During the experimental trials (both learning and generalization), the experimenter recorded the correct and incorrect anticipations. Once the experiment was completed the experimenter recorded the pertinent data and this was independently checked at a later time.

The order in which the paradigms were run was determined at random. The subjects were assigned numbers (1–144) in order of their appearance and randomization was carried out with the aid of a table of random digits (Rand Corporation, 1955). Eighteen subjects were randomly allocated to each paradigm. The writers both served as experimenters, the assignment to subjects being made on a chance basis.

Statistical Design

Prior research by the authors and their associates had indicated that it would be advantageous to use each subject as her own control, since intersubject variability was sufficiently great to conceal important generalization effects. Such an experimental manipulation is analyzed most adequately by treating it as a split-unit design (essentially the same as a split-plot design). This type of analysis yields information on the significance of interparadigm differences (whole units), intraparadigm differences (subunits), and the interaction between the whole units (paradigms) and the subunits (experimental vs. control pairs). The latter tests are more sensitive than the first in as much as the main effects are confounded in the split-unit design (see Kempthorne, 1952; Lindquist, 1956). A further consideration in the use of this design was that several paradigms had not been previously investigated and

increased sensitivity is provided on the important subunit tests.

Since each subject was given only one experimental treatment, or allocated to only one paradigm, the estimates of the mean generalization effect and the variances are independent from paradigm to paradigm, and t tests can be performed on each paradigm. This is, of course, supplementary to the analysis of variance outlined above, which tests the effect of experimental vs. control pairs over all paradigms.

Differences between the paradigms were evaluated using the Tukey *hsd* test (see Federer, 1955) where one can legitimately make any number of nonorthogonal contrasts or even test a posteriori hypotheses using confidence limits and adjusting the width of these limits according to the number of contrasts made. Each paradigm was then tested against every other paradigm for significance of difference.

Results and Evaluation of Hypotheses

A split-unit design divides the data into two subsets, one involving the whole unit or treatment variable and its error variance estimate, and a second involving the subunits and subunit × treatment interaction with its error variance estimate. The presentation of the results will then follow this format: first, the analysis of the overall subunit effects and the subunit × treatment interaction, followed by t tests for generalization effects for each paradigm; second, a test of the overall whole unit or treatment effects, followed by specific contrast between paradigms as outlined by Hypotheses 2, 3, and 4. The dependent variable is, in all cases, the difference between the number of correct anticipations of the control pairs versus the number of correct anticipations of the experimental pairs in the five-trial third stage of each paradigm.

Subunit Effects: Presence or Absence of Generalization

The overall analysis of variance for all eight paradigms is presented in Table 2. The F ratio for the subunits is 69.70 which has a probability value of less than .000001. In view of these findings, which are surprising only in their magnitude, there can be little doubt about the occurrence of generalization with models such as these. However, the question still remains as to which of the paradigms account for these effects.

When we turn to the individual paradigms involved in this study, we find the effects equally positive. Table 3 presents the means, standard deviations, t values, and appropriate probabilities for each of the eight paradigms. The fact that all paradigms except one surpass a significance test at the .05 level, coupled with the results of the overall F test for all eight paradigms, leaves little doubt as to the general tenability of Hypothesis 1. It should be noted that all paradigms except III and IV would pass a significance test at the .01 level. Of course, some question arises concerning the failure of Paradigm III to show significant generalization. But with the similiarity of mediation processes in Paradigms III and IV, as well as the highly significant generalization obtained with the remaining paradigms, it seems possible that the lack of more positive results with Paradigm III may be attributed

TABLE 2

Analysis of Variance for the Eight Paradigms

Source	*df*	*SS*	*MS*	*F*
Treatments (T)	7	149.6111	21.3730	0.90
Error (a)	136	3228.5000	23.7390	
Subunits (S)	1	485.6805	465.6805	69.70**
S × T	7	80.0417	11.4345	1.60
Error (b)	136	947.2776	6.9635	
Total	287	4891.1111		

** $p < .01$.

TABLE 3

MEANS, STANDARD DEVIATIONS, AND t TESTS OF THE GENERALIZATION EFFECTS (DIFFERENCE BETWEEN EXPERIMENTAL AND CONTROL WORDS) FOR EACH OF THE EIGHT PARADIGMS

Statistic	Paradigm							
	Response chaining				Stimulus equivalence		Response equivalence	
	I	II	III	IV	V	VI	VII	VIII
M	3.06	2.28	.44	1.83	2.39	4.00	3.61	3.17
SD	3.39	3.06	3.36	3.62	3.93	5.05	3.65	3.45
t	3.83	3.17	.56	2.15	2.58	3.36	4.20	3.91
p	.0008	.003	.32	.025	.009	.002	.0003	.0006

to an individual difference factor occurring by chance in the subject sampling process. This possibility is partly supported when the experimental and control pairs are considered separately. Table 4 presents the relevant data.

Note that the total for control pairs is larger for Paradigm III than for the remaining paradigms while the total for experimental pairs is virtually identical with the total for Paradigms II and IV. Of course such data are by no means conclusive, but the possible importance of individual differences is at least suggested here. Some additional considerations on this point will be presented in the discussion section.

The F ratio for the subunit × treatment interaction fell short of the value necessary to reject the null hypothesis at the .05 level. This adds support to whole unit analysis to be discussed shortly, which shows no evidence for treatment differences.

Whole Unit Variation-Differences between Paradigms in Generalization Effects

Table 2 indicates that the F ratio for the whole unit variable is .90, which is not significant. Ordinarily one would stop at this point and perform no further tests, inasmuch as such tests would not be statistically meaningful. However, in exploratory research, one frequently makes such contrasts anyway, to gain a more sensitive view in the point estimates. Such tests were made utilizing Tukey's *hsd* (cf. Federer, 1955), and even the largest difference, the difference between Paradigms III and VI was

TABLE 4

TOTAL CORRECT RESPONSES ON EXPERIMENTAL (E) AND CONTROL (C) PAIRS FOR EACH OF THE EIGHT PARADIGMS

Pair	Paradigm							
	Response chaining				Stimulus equivalence		Response equivalence	
	I	II	III	IV	V	VI	VII	VIII
E	188	149	151	147	146	180	192	178
C	133	108	143	114	103	108	127	121
Total	321	257	294	261	249	288	319	299

not great enough to reject the null hypothesis at the .05 level. Thus the null hypothesis counterparts of Hypotheses 2, 3, and 4 cannot be rejected.

The reader will recall that in the discussion of split-unit analyses it was pointed out that the gain in sensitivity for the subunits and subunit × treatment interaction is at a sacrifice in sensitivity in evaluating differences between treatments (or paradigms); therefore, it remains worthwhile to examine the nonconfirmed hypotheses in terms of the point estimates (means) of the generalization effect. Table 3 includes the means and standard deviations of each of the eight paradigms.

Hypothesis 2 stated that Paradigms I, II, VI, and VII would show greater generalization than Paradigms III, IV, V, and VIII. The difference between the mean effects of these groups is 1.28, a difference of moderately large magnitude and in the right direction. Thus Hypothesis 2 is confirmed with respect to the directionality of the differences.

Hypothesis 3 stated that Paradigms I, IV, VII, and VIII would show larger amounts of generalization than Paradigms II, III, V, and VI. The difference between the means of these sets of paradigms is .69, and again the directionality is confirmed though the magnitude of the difference is small and unimpressive.

Hypothesis 4 was not stated in a statistically testable form unless one is willing to hypothesize that all sets of paradigms will be significantly different from all other sets of paradigms. This hypothesis predicts that in the order of the magnitude of the generalization effect the paradigms will align themselves in groups with Paradigms I and VII showing the greatest generalization effects, followed by Paradigms II and VI; IV and VIII were predicted to be the third strongest set and Paradigms III and IV were expected to be the weakest. From Table 3 it can be seen that all of these predictions held. The mean generalization effects for the four groups are as follows:

I and VII	II and VI	IV and VIII	III and V
3.34	3.14	2.50	1.42

Thus Hypothesis 4 is also confirmed with respect to direction. Again, no differences are significant.

In summary then, it may be said that Hypothesis 1 was strongly confirmed by the overall analysis of variance and by individual t tests of the paradigms; Hypotheses 2, 3, and 4 lacked statistical confirmation, but these hypotheses were correct in predicting directionality of observed differences and in predicting the relationship between the paradigm effects.

Discussion

The model presented earlier is based on the assumption that mediated generalization occurs in all paired-associate learning situations in which some common element has been associated with two otherwise independent elements. The present study was designed to test this assumption and to investigate the nature of the mediational process in a particular subset of verbal learning tasks.

In addition to the overall effects, it was postulated that two factors in the mediation process would determine the amount of generalization to be expected in the eight paradigms. These two factors, directionality of associative connections and contiguity between explicit and implicit elements, were used to make predictions about the relative magnitude of generalization effects in these paradigms. These factors are illustrated in the paradigms presented in Figure 4.

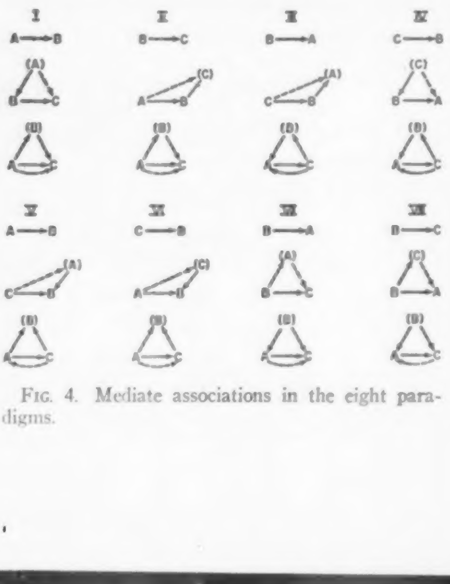

FIG. 4. Mediate associations in the eight paradigms.

The results presented in the preceding section leave little doubt as to the plausibility of the general assumption, at least with paired-associate learning paradigms. The magnitude of the F ratio of the subunit effects coupled with the individual t tests, seven of which have probability values less than .05, can be interpreted as a strong confirmation of Hypothesis 1. A possible exception exists, due to the failure of one of the chaining paradigms to show significant generalization effects.

The postulated bidirectionality of associational links also received considerable support from this experiment. It can be seen that six of the seven significant paradigms utilize at least one reverse association in either the second stage learning or the test stage. Although most paradigms rely on some combination of the forward and reverse association to account for the generalization effect, three of the significant paradigms have a reverse connection in both mediational stages (Paradigms IV, V, and VIII). The importance of forward associations is clearly demonstrated in the magnitude of the generalization effects for Paradigms I, II, VI, and VII, whereas support for the factor of reverse association is provided by the presence of generalization effects in Paradigms IV, V, and VIII. Presumably, if it were not for these reverse connections, Paradigms IV, V, and VIII would show no generalization effect at all. These results strongly suggest that forward associations alone simply do not provide an adequate basis for explaining all mediational effects. It should be noted that this finding has obvious implications for advocates of representational models of mediation, since none of these models provide for bidirectionality.

Even though the predicted differences between paradigms with forward and reverse connections were not significant, the data concerning the bidirectional factor also lends support to the assumption about the relative strength of forward and reverse associations. Although this investigation was not designed to determine the empirical relation of these connections, the data suggest that forward links are stronger. This can be illustrated by comparing Paradigms V with VI and VII with VIII. The only difference between V and VI is in the directionality of the implicit association formed during the second stage learning trials. From this, we predict that VI will show more generalization than V. It can be argued that Paradigm VII should produce more generalization than Paradigm VIII on a similar basis. Both of these predictions are confirmed. In addition the relatively small mean generalization effects of Paradigms III and IV, which have reverse mediational connections lend additional support to this assumption.[4] The fact that a consideration of the directionality factor alone does not lead to a clear-cut separation of the paradigms may be partially accounted for by the multiplicity of factors which evolved—both those which were postulated and others which were suggested by the data.

The second factor proposed, contiguity in the second stage mediation process, is more difficult to evaluate. As mentioned in the results section, the difference between sets of paradigms with postulated contiguous mediators as opposed to those with noncontiguous mediators was small, but in the predicted direction. Unlike the bidirectionality factor, presence or absence of generalization in any paradigm is not a crucial test of this mechanism. In view of this, perhaps the best supplementary evidence can be gained by contrasting those paradigms which differ only in the contiguity of the second stage mediator. Such differences are found only among the chaining paradigms. By contrasting Paradigm I with II and III with IV, it can be shown that differences in generalization effects are observed and these differences are larger than the pooled effect of all contiguous vs. noncontiguous mediators (Hypothesis 3). Although these interparadigm effects are not significant, the consistency of these results lends considerable support to the contiguity argument. Of course, alternative explanations, e.g.,

[4] It should be pointed out that the paradigm which had all forward associational links, Paradigm II, did not show the greatest amount of generalization.

the magnitude of generalization depends only on the directionality of the associative links, or contiguous and remote connections are equally strong, remain plausible. On the basis of the experimental design used here, it seems premature to make any final judgment as to the importance of the contiguity factor, although its operation received some support.

The final assumption made in the proposed mediational model was that direction of association would be a more important factor than contiguity. The results given earlier also support this assumption. Although no differences were significant, the mean generalization effects, for pairs of paradigms, were in the exact order predicted in Hypothesis 4. Further evidence on this assumption may be gained by considering separately the chaining paradigms and the equivalence models.[5] Hypotheses analogous to Hypothesis 4 can be generated for each set of paradigms, and within each set the paradigms can be ordered on the basis of the two principles under investigation. The data in Table 3 indicate that this way of viewing the results leads to complete predictability in the rank order of the chaining paradigms and only one deviation in the predicted order of the equivalence paradigms. This interpretation involves no change in the factors previously mentioned, either as to operation or importance, and the one deviation from predicted order involves only the less well-established contiguity principle. Even this one deviation may be due to differences in heterogeneity of subjects (see Table 3) rather than a failure of the contiguity principle. Of course, these are somewhat speculative deductions and must wait verification using an experimental design which maximizes sensitivity on interparadigm effects.

In conclusion then, the data obtained in this experiment strongly confirm the bidirectional interpretation of mediational processes. In addition, the importance of implicit connections formed during the second learning stage is strongly supported on the basis of confirmed predictions based on either bidirectionality or contiguity of explicit and implicit terms.

Facilitation vs. Interference

The analysis presented here assumes that the generalization effects obtained are truly the result of facilitation in the learning of experimental pairs, and not the result of interference in the learning of control pairs. Either or both interpretations are possible. The difference can be illustrated by examining the test stage for mediational and nonmediational pairs in Paradigm I as illustrated in Figure 5.

Whether one argues for facilitation or interference, the mediational pairs will be learned faster. However, the interference argument is based on the assumption that the A⟶D connections will slow down or interfere with the learning of A⟶C pairs, whereas the facilitation argument assumes that the A⟶C pairs will be learned faster due to the implicit chain of previously formed associations. No resolution of this difference is possible here, but an analysis of the results from the second stage, which provides a comparable situation, is informative. The comparison analogous to that presented above can be best illustrated using the classical interference model (Paradigm VII).

Stage 1 B/D⟶A
Stage 2 B⟶C

Keeping in mind that D represents control words it can be seen that half of the pairs involve stimulus words in the second stage which are entirely new terms (i.e., B words not present in Stage 1). The remaining pairs contain B words previously associated

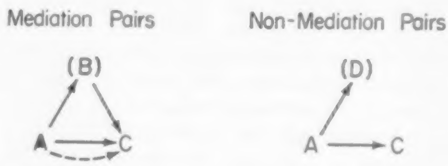

FIG. 5. Experimental versus control pairs in the test stage of Paradigm I.

[5] These paradigms were separately treated in two previous papers by Horton (1959) and Kjeldergaard (1960).

TABLE 5

DIFFERENCES IN THE NUMBER OF CORRECT ANTICIPATIONS ON FAMILIAR PAIRS MINUS NEUTRAL PAIRS (F − N) DURING STAGE 2 LEARNING

	I	II	III	IV	V	VI	VII	VIII
F − N	−3.33	−.28	.33	−.50	−1.39	1.50	1.44	.78

with A words. Facilitation in the latter case would be explained on the basis of familiarity with these B words and interference would be accounted for by assuming that previously learned B⟶A associations make it difficult to learn the new B⟶C connections. In any case, if the connections between new B terms (i.e., those not appearing in Stage 1) and C words are formed more rapidly than the connections between familiar B terms and associated C words, the interference position would be strengthened. The data relevant to this comparison are given in Table 5.

The results do not favor either interpretation as the interference or facilitation effects vary widely from paradigm to paradigm and the mean interference effect (F-N) over all paradigms is only −.18. Since the interference effect is so small in this case, it seems unlikely that interference could account for much of the test stage generalization effect. The general lack of support for familiarity has no real implication for the test stage. Thus, it appears that the generalization effect observed in this experiment is in all probability the result of facilitation in the learning of experimental pairs as the model suggests.

The Nonsignificant Paradigm

One of the questions arising from this investigation concerns the failure of Paradigm III to show significant generalization. If this lack of significance is viewed as indicating no mediational effect, then serious question arises concerning the existence and importance of the reverse associative factor proposed here. However, since the mediational factors in Paradigm III are so similar to those of Paradigms IV and V, which showed significant generalization effects, other interpretations seem more probable.

Perhaps the most parsimonious explanation of the results obtained with Paradigm III is that the degree of generalization is low. If this is the case, a larger number of word pairs or a greater number of trials in the learning stage will be needed in order to demonstrate significance. It should be remembered that Paradigm III was expected to be weaker than most others and that the paradigm next lowest in observed generalization effect, IV, was identical to Paradigm III with respect to the important directionality factor.

An alternative way of viewing the results is that a mediating effect exists with Paradigm III but that it is lost with the particular subjects used in this experiment. If this is the case, the data should reveal some peculiarities for these subjects. In an earlier section it was noted that the subjects in Paradigm III showed a high frequency of correct anticipations on the control pairs (more than any other paradigm) while their frequency on the experimental pairs was approximately equal to that of the subject in Paradigms II, IV, and V. These data suggest that the subjects of Paradigm III were "fast learners," a point which is further supported when the data of Table 6 are examined. It can be noted that the Paradigm III subjects are the fastest on the important second stage list, and second fastest on total trials. Now if this speed of learning interpretation is valid for these subjects, on the paradigm which is theoretically one of the two weakest, it is possible that the frequency of exposure to the pairs was not sufficient to bring the associative connections above threshold. The other two paradigms

TABLE 6

TRIALS TO CRITERION IN THE LEARNING STAGES OF EACH PARADIGM

Stage	I	II	III	IV	V	VI	VII	VIII
1	288	360	287	274	310	267	337	229
2	239	235	182	197	215	188	200	203
Total	527	585	469	471	525	455	537	502

(IV and VI) which reflect comparable learning speed show either a more favorable contiguity or directionality factor which may have required fewer exposures in the learning stages to show generalization effects in the test stage.

Obviously post hoc analyses such as these must be viewed somewhat skeptically. The next step would be to perform another experiment using more word pairs or requiring a greater exposure frequency. Such an experiment would provide a satisfactory answer to the questions raised here.

Subjects Who Fail to Generalize

The present investigation leaves little doubt concerning the existence of generalization effects with seven of the eight paradigms. However, before any definite conclusions can be drawn about the process involved, the failure of several subjects to generalize must be examined. Table 7 indicates the number of subjects who generalize (i.e., learn more experimental than control pairs) and do not generalize (i.e., experimental pairs are equal to or less than control pairs) for each paradigm.

Using this somewhat liberal definition of generalization and considering only those paradigms showing significant generalization (i.e., all except III), it can be seen that 25% of the subjects do not generalize. This figure represents too great a portion of the sample to attribute the results to experimental error, though many investigators with similar results seem to ignore this phenomenon. Such a resolution of the problem is untestable and should not be used in the absence of more serious attempts to investigate alternative explanations.

Since earlier investigations (e.g., Peters, 1935) had encountered the problem mentioned above, an attempt was made during the experiment to look for potential explanatory factors. One way of doing this, however crude, was to question the subjects about their method, and attitude toward the experiment, after they had served as subjects. This was done whenever time permitted. It was felt that data obtained in this manner might reveal such things as the importance of difference in the speed with which subjects "catch on" to the experiment. The data obtained indicate that *none* of the subjects questioned realized the exact nature of the task. This appeared to be the case whether they were questioned on this point before or after the experiment was explained. As Bugelski and Scharlock

TABLE 7

INDIVIDUAL SUBJECTS SHOWING GENERALIZATION IN EACH PARADIGM

Subject	I	II	III	IV	V	VI	VII	VIII
Generalizers	15	14	9	11	14	14	14	13
Nongeneralizers	3	4	9	7	4	4	4	5

(1952) discovered, there appeared to be no realization of the presence of a common term as a mnemonic device during the learning stages. Furthermore, the subjects were so completely unaware of this factor that they accepted erroneous explanations of the experiment as readily as the true one. Thus, it seems clear that the experimental findings presented here are not dependent on "awareness," "insight," or conscious use of associative mediators. Yet within this apparently "unaware" group, differences are found which need to be accounted for.

Within the context of the associative factors suggested earlier, an obvious variable to examine in accounting for subjects failing to generalize is that of individual threshold level. Some subjects (due to individual difference factors of a sort) may not have received sufficient exposure on the pairs to raise the habit connections, necessary for mediation to take place, above threshold. Although this explanation may be acceptable for Paradigm III, and is roughly supported by a comparison of the data presented in Tables 6 and 7, the account is not especially impressive for the remaining paradigms. Of course, this is not to say that the exposure argument is totally irrelevant, because exposure frequency may be related to other factors.

Examination of the data obtained in this experiment and questioning of the subjects suggest several factors which appear to be related to the degree of generalization. Perhaps the most obvious of these variables is the speed with which individuals learn. When the amount of generalization is examined as a function of the number of trials required to learn Stage 1 (see Table 8) it can be seen that the mean level of generalization increases sharply from the first to the second block of trials, and after a drop off, remains at a level considerably above that for the first block. This increase in generalization supports the threshold argument presented above. It should be noted that this comparison is not rigorous since there is no effective counterbalancing with respect to lists, paradigms, or subject learning speed.

Examination of the raw data shows that the mean level of generalization among the 10 subjects taking six to eight trials on Stage 1 is only .60. Just why this occurs is not clear, although it may be that individuals who are very fast learners may operate under some combination of set or ability factors which are different from those of the other subjects. Such factors may lead to extremely rapid learning but at the same time decrease the likelihood of generalization.

That the learning factor mentioned above may be a complicated one is supported by the questioning of subjects. Such data suggest two factors which in turn may interact with whatever ability factors are involved in paired-associate learning. The first of these is concerned with the subject's conception of what he is supposed to do; this might be referred to as task set. The second is related to the subject's method of strategy (i.e., how he performs the task). For example, it is possible that the usual instructions establish a set, or determine a method, that increases the number of exposures necessary to raise habit strength above threshold. The exact nature of such sets, and the degree to which they can be modified by instructions, must be determined experimentally. However, consider the possibility that there is some set, or method, or combination of the two, for which the frequency of exposure necessary to raise connections above threshold is at a minimum. Now, if either the set or method is not of this optimum variety it may be that the exposure fre-

TABLE 8

Amount of Generalization as a Function of Learning Speed in Stage 1

Trial	Generalization	
	M	*N*
6–10	1.48	23
11–13	3.38	24
14–15	2.46	24
16–18	2.53	30
19–24	2.38	21
25–35	2.55	22

quency must be greater to form connections of equal strength. These factors might be investigated by varying the type of instructions given to the subjects, since the instructions presumably play an important part in determining task set and strategy.

In view of the above considerations several parameters can be suggested which should be important in the type of generalization situation investigated here. First, each paradigm presumably requires a certain frequency of exposure during the learning stages. This frequency is a function of the variety of associative connections required for mediation. Second, each individual has an exposure parameter with respect to each paradigm, although it is likely that the relative rank for each person, in terms of number of trials, is approximately the same across all paradigms. Third, some sort of optimum set exists for the production of mediated generalization. Fourth, and last, some sort of optimum strategy exists for producing generalization. Of course, it should be made clear that individual differences in the ability to generalize will not disappear even under ideal conditions. Such an ability, which may involve the breadth or narrowness of previous learning, the ability to put two and two together, or the tendency toward concrete or abstract thinking, presumably determines the upper limit for generalization in any such situation.

Conclusions

The data obtained in this investigation tend to support the notion that generalization can be obtained with all mediational models, although Paradigm III may require additional learning trials in order to raise the strength of reverse connections above threshold, or more mediational pairs to demonstrate the effect. In addition, the associative factors suggested here, at least those concerning the strength of forward and reverse associations and their corresponding thresholds, tend to be supported. Further research, however, will be needed to establish more clearly the influence of the factor of contiguity in association. Finally, there is a suggestion that some kind of task set or strategy may be important in explaining the lack of generalization obtained with some of the subjects in paradigms showing highly significant generalization.

Summary

This investigation was designed to shed light upon the role of mediate association in verbal generalization processes. Although the systematic formulation of this concept goes back to Hull's early papers, the research dealing with it has been quite limited in scope and relatively unsystematic. The previous work on such models has been done largely with verbal materials in the context of paired-associate learning. These studies have suggested several factors, such as reverse association and contiguity of mediating links, which may be important in the generalization process. In addition, these factors lead to the consideration of mediate association models where the mediation takes place during the learning stages as well as the traditional final stage. The present experiment constituted an attempt to discover which of eight paradigms would show positive facilitation effects and which factors might account for such facilitation as well as differences between paradigms in the degree of facilitation of generalization.

The experiment involved a three-stage paired-associate learning task in which stimuli or responses were equated, or in which response chains, e.g., A⟶B, B⟶C, were formed, in the first two stages, followed by a test stage in which the equated stimuli or responses, or the first and last members of response chains, were paired with each other and the amount of generalization or facilitation noted. Combining word pairs into a three-stage paired-associate learning task yields eight paradigms in all: four response chaining, two stimulus equivalence, two response equivalence.

An analysis of the possible mediating links in these paradigms leads to the conclusion that for most of the paradigms to show any generalization effects, backward or bidirectional association seems to be a necessary explanatory construct. That is,

one has to postulate that the learning of an A⟶B pair simultaneously results in the formation of a B⟶A habit, the strength of which is some function of the A⟶B pairings. Several other investigators have provided data which support such an assumption (Jantz & Underwood, 1958; Murdock, 1956, 1958; Russell, 1955). Most of the available theories of mediated generalization, however, have completely ignored the problem of backward or bidirectional mediators (cf. Cofer & Foley, 1942; Mowrer, 1954; Osgood, 1952); Jenkins (1955) and Russell (1955) have dealt with it informally.

A second factor, contiguity of the mediator in the second stage learning, was postulated to account for anticipated differences between certain subsets of the paradigms, namely, two chaining paradigms and the stimulus equivalence models versus two other chaining paradigms and the response equivalence models. In the stimulus equivalence models and two of the chaining paradigms, the second stage implicit response, ( ), would necessarily follow the explicit response term; whereas in the response equivalence models and the other two chaining paradigms, the mediator would presumably follow the stimulus and antedate the response. Thus the second stage processes in the stimulus equivalence and two of the four chaining paradigms can be conceptualized as learning the chain C⟶B⟶(A) or A⟶B⟶(C), as opposed to the cases of the response equivalence models and the other two chaining paradigms where the chains would be B⟶(A)⟶C or B⟶(C)⟶A. Since the test stage for all paradigms involved learning an A⟶C pair, it was assumed that the contiguous mediational links formed in the second stage pairing in the response equivalence models and two chaining paradigms would show more generalization strength than the more remote pairings in the stimulus equivalence paradigms and in the other two chaining paradigms.

The materials used in the experiment were low frequency five-letter real words selected from the Thorndike-Lorge lists (1944). A large number of words selected on a frequency criterion were subjected to tests for association value. The words finally selected were randomly assigned to four lists and these four lists were permuted to form 12 lists of eight word pairs. These 12 lists permitted complete counterbalancing of list difficulty in the test stage and partial counterbalancing of list difficulty in the two learning stages.

Earlier experimentation had suggested that individual differences in paired-associate learning are so great that they might easily mask the generalization effect unless these differences were controlled. Therefore, a split-unit design was utilized with each subject acting as her (all female subjects) own control. The test stage of each paradigm was made up of eight word pairs, four of which were generalization pairs and four of which were control pairs. The dependent variable, then, was the difference between the generalization pairs and the control pairs.

The results of this investigation clearly establish the presence of generalization effects for all paradigms except one of the chaining models. The F ratio for subunits (a test of the null hypothesis that there were no mediational effects in any of the paradigms) was 69.70. An F ratio of this magnitude could be expected to occur by chance about one time per million. Of the eight t tests performed on the individual paradigm effects, seven were significant at the .05 level or beyond. No paradigm was significantly different from any other, though the predictions about the relative magnitudes of the generalization effects for the eight paradigms made on the basis of the two postulated factors, bidirectionality and contiguity of mediators, were all confirmed with respect to the direction of the observed differences. The results for the nonsignificant paradigm were positive, though small.

A split-unit analysis sacrifices between-paradigm sensitivity in favor of the sensitivity in detecting within-paradigm effects; therefore, final conclusions about paradigm differences must be held in abeyance.

These results confirm the importance of both forward and reverse mediate associa-

tions in the verbal transfer process. Furthermore, there is sufficient evidence for both contiguous and noncontiguous mediate associations and implicit rehearsal of previously learned associations to warrant further research on these factors. In an attempt to discover reasons for some subjects' failing to generalize with paradigms which show in general highly significant generalization effects, whenever possible the subjects were questioned about their attitudes and strategies. The answers given suggest that task set (e.g., what is supposed to be done?) and strategy (e.g., how is it supposed to be done?) may be important variables in obtaining generalization. In any case, further investigation of these variables seems necessary.

In conclusion, this study has clearly established the presence of generalization effects with three chaining, two acquired stimulus equivalence, and two required response equivalence paradigms, and has strongly suggested the presence of several associative factors and indicated a need for further investigation of others. In addition, individual difference factors, such as task set and strategy, appear as important parameters in generalization and warrant further investigation.

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